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BRADFORD KNAPP, *Director.*

SEPTORIA GLUME BLOTCH OF WHEAT

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Introduction

A very marked spotting of glumes and rachisis of a large number of wheat varieties has been under observation in Arkansas. For three successive seasons the wheat around Fayetteville has been severely attacked and due to the rush of work no attention was given to it until recently. Indeed, the only work done thus far by the writer has been to identify and compare this with other glume spotting heretofore described and to attempt some preliminary infection experiments. It may perhaps be desirable to call attention to this disease at this time since it is said to be serious in Europe and since the records of its occurrence in America are confined to a few notes which, very briefly, call attention to a Septoria associated with a glume spot. Besides being almost unknown in this country, no infection experiments have been attempted either here or abroad and proof of the pathogenicity of the organism is based entirely upon circumstantial evidence, namely, that of association with diseased spots.

Symptoms

The most conspicuous symptoms are to be observed on the glumes, particularly the outer glumes. (See fig. 1.) The attacked parts are noticeably discolored, the discoloration appearing as brownish or purplish-brown spots or blotches, often with a hoary appearance, or brownish with a grayish-white center. The spots vary in size from 2 to 10 mm. or more, and no definite shape is ordinarily discernible. The upper parts of the glumes, which include the beards in bearded varieties, are the parts most likely to be attacked, although discolored spots are also to be observed on any part of the head, including the rachis. Upon the rachises, the discolored areas are found at or near the joints, occasionally extending over the entire internode, but in any case with no sharp boundary. When attacked nodes are cut into the discoloration may be noted in the interior tissues although not as pronounced as on the exterior; likewise, the interior surface of the attacked glumes is not as conspicuously discolored as the exterior. As compared to the black chaff disease, common at times around Fayetteville, the attacked parts are not as sharply delineated, usually lighter brown in color, and with no tendency to form streaks

Fig. 1. Glume blotch on Kan Red (bearded) and Red May varieties. (Slightly enlarged.)

or stripes, one of the characteristic symptoms of black chaff. Compared to "scab" of wheat, rather rare in Arkansas, (Atanasoff (1) was unable to find any in this state), the attacked parts are considerably more discolored, there is little or no discoloration of heads attacked by Fusarium-blight, according to the same author, and the attacks in Septoria blotch are always more or less localized. The term "blotch" is used in preference to "spot" because of the irregular and indefinite nature of the discoloration.

Besides attacks on the heads, Frank (10 and 11) records leaf-blades as also attacked by the same fungus. The present writer has noted spots on leaves, frequently on parts of the sheaths at or near the nodes, which closely resemble the spots on the glumes; the peculiar greyish-white, hoary appearance on a purplish-brown background so characteristic of glume spots has also been noted on the leaf sheaths, and blades, and very often at nodes.

Moreover, the same fungus has been observed in leaf spots as in glume spots.

Previous Records of the Disease

European Accounts

In 1845 Berkeley (3) described *Septoria nodorum* as producing spots on nodes of wheat in England. His description, as given by Grove (12), reads as follows, "Spots pale fawn-coloured, with a dark border, depressed, at length confluent; pycnidia slightly prominent; spores oblong, very slightly curved or irregular, containing a row of guttules. Makes its appearance at first under the form of little discoloured depressed spots on the nodes of the stem, especially the upper ones." Somewhat later Passerini described what appears as the same disease, according to Grove (l. c.), on the glumes of wheat in Italy. He also considered the pathogen a species of *Septoria*, giving it the name *S. glumarum*.

Since the spores of this pathogen vary considerably, even at maturity, it is not surprising that other writers should have overlooked the possibility of considering it a species of *Septoria* and have assigned it to other genera. Thus Kuehn (14) in 1877, paying no attention to Berkeley's work, described a new species of *Phoma* parasitic on wheat heads, especially the glumes. His description of the disease, translated, reads as follows:* "It attacks particularly the upper half of the outer and inner glumes, also attacking at times down to the base of the outer glumes. The attacked parts take mostly a dirty grayish-violet appearance, which gradually become whitish-grey, the seat of the punctiform pycnidia." "By early and copious infections *Phoma Hennebergii* causes a reduced development, and in very unfavorable conditions even complete impoverishment of the seed, besides lessening in considerable degree the fodder value of the chaff."

In 1890 Ericksson (9) found the same disease near Stockholm. Forty acres of summer wheat were so heavily attacked that the whole field appeared red in the distance and a sound head was difficult to find. The kernels were off-color, shrunken and useless. On nearly every inner and outer glume one or more large, irregular, chocolate-brown spots were noted.

* "Er tritt vorzugsweise an der oberen Haelfte der Klappen und Spelzen auf, geht bei erstern aber auch zuweilen bis an die Basis herab. Die befallenen Theile nehmen meist ein schmutzig grauviollettes Ansehen an, das an den Stellen allmaehlig in Weissgrau ausbleicht, wo die punktfoermigen Perithecien hervorkommen.—Bei fruehzeitigem und haeufigem Auftreten verlansst Phoma Hennebergii eine minder vollkommene Ausbildung, in sehr unguenstigen Faellen selbst voellige Verkuemmerung des Samens, benachtheiligt auch in erheblichem Grade den Futterwerth der Spreu."

Frank (11, p. 398 and p. 419) observed the disease in various localities in northern Germany. Attacked heads showing spotted glumes were found to be more or less numerous. Concerning the attack on leaves, he says, "Since 1894 I have found the fungus attacking the leaves as well as the glumes of wheat."

Various other European authors, including Sorauer, Tubeuf, Massee, and others, mention this disease but confine themselves to Kuehn's original description and add but little or nothing to the first accounts. The most recent references found by the writer are by Diedicke (7 p. 193 and p. 468) 1912 and 1914, and by Grove (12) 1916. These accounts are primarily devoted to the fungus.

From these descriptions, particularly those of Kuehn's and Eriksson's, it will be noted that the parts of the plant attacked and the nature of the attack correspond to that observed in Arkansas. The writer, through the kindness of Dr. W. A. Murrill of the New York Botanical Garden, and also through Dr. E. A. Burt of the St. Louis Botanical Garden* has been enabled to examine some of Kuehn's original material (Rabenhorst, Fungi europaei No. 2261) and comparing it with Arkansas material finds them very similar both macroscopically and microscopically. (See fig. 2.) Besides the symptoms, the fungus found associated with the diseased parts in both Europe and America is similar and evidently the same species.

American Accounts

In contrast to the rather numerous European references, the disease thus far has hardly attracted attention in America. The first accounts appeared in 1898, one by Townsend (17 p. 126) from Maryland, and the other by Selby (16 p. 42) from Ohio. Townsend's account reads as follows:

"During the past season the wheat crop in certain sections of our State has been greatly injured by - - - a species of *Septoria* (probably *Septoria glumarium* [sic]). It does not appear that this fungus has heretofore produced any damage to wheat in this State, although it has been seen in Europe and possibly in some parts of our own country. I have not been able, however, to find any account of its appearance in America. It is seen soon after the heads are formed, and attacks the straw, leaves and glumes, but does not attack the grain itself. It spreads rapidly over the individual plants, and from plant to plant, and draws so much nourishment from its host just at the time when the heads are filling, that the kernels are very much shrivelled. It often appears most distinctly upon the heads, giving

* The writer gratefully acknowledges the help of Dr. J. A. Elliott in examining and securing material from Dr. Burt, and in looking up certain references.

Fig. 2. Two heads at left showing glume blotch, Arkansas material. Head at right showing glume blotch, European material, (Phoma Hennebergii—Rabenhorst, Fungi europaei No. 2261)

them a dirty appearance. Upon close examination the infected parts are seen to be covered with numerous small, black dots which are masses of spores in little cavities (Pycnidia). It is impossible to estimate at this time, the amount of damage done by this fungus during the past season, but in a single instance, one field that gave every indication of producing from 30-35 bushels per acre of A. No. 1 wheat was so injured in a few days by this pest that the yield was reduced to 15 bushels per acre of inferior grain. In other sections the degree of injury has been more or less marked. It has been impossible to investigate the disease fully during the past season. If it appears next year it will receive special attention, the results of which will be published in another bulletin.

"It is probable that the suggestions given for the prevention of rusts (use of early maturing varieties and rotation) will in a measure prevent the destructive action of this disease."

This account leaves little doubt that the same disease as found in Arkansas is considered, although descriptions of the fungus, particularly of the spores, are missing and the possibility of attacks by *Septoria graminum* Desm. on the leaves must not be overlooked. Under the heading "Glume spot" Selby gives the following account, "The glumes of certain varieties grown by the Experiment Station, are frequently spotted by a pycnidial fungus. These dark spots are very conspicuous upon Velvet Chaff, the sort used as a standard in variety comparisons. Other varieties are more or less marked in the same manner. The fungus, in this case, appears to be one of the form genera and has been referred to Septoria." This brief description is hardly sufficient to place the disease definitely, but the reference to glume spots without leaf infections would make it appear that the disease producer is the same as the one under consideration. (*Septoria graminum* and *S. Tritici* are not known to attack glumes.) Davis' (6 p. 685) note of *Septoria glumarum* on dead, rusted leaves of wheat collected at Athelstane, Wisconsin may refer to the same fungus but since nothing is said of association with diseased or discolored spots it is not certain whether he treats of the disease which is here being discussed.

The only other American reference which may be considered to deal with the same disease is a recent note by Clinton* (4 p. 481). His description reads, "Glume Blotch, *Septoria* sp. We collected this fungus once or twice in our disease survey work in 1918 as a very inconspicuous parasite on the glumes and leaves of wheat."

Two other American references should be noted, although it is very doubtful if the same disease is treated. Attention is

* The writer is indebted to Miss Edith K. Cash of the U. S. Department of Agriculture for this and other references.

called to a "*Septoria* blight of wheat - - - among those of special importance" in the State of Washington (18 p. 21), and Peck's account (15 p. 58) of *Macrophoma suspecta* (new species) as occuring on large leaf areas of dead basal leaves of winter wheat, in Kentucky.

The Pathogen

Berkeley's original description of the disease as well as the associated fungus has already been cited. The account of the pathogen is very brief, no spore measurements are given, and it is due to Grove's (12) study of Berkeley's original material which makes it possible to identify *Septoria nodorum* with the disease under discussion. Grove has studied Septorias of wheat found in England and West Australia and as a result of these studies he concluded that *S. glumarum* Pass. was the same as *S. nodorum* Berk. He presents the following description:

"Pcynidia on the dead parts of the leaves, but without any distinct spots, very numerous, epiphyllous scattered all over the leaf, but arranged in short lines, somewhat crowded, 70-100 mic. in diameter, honey-coloured with a reddish tinge, then black, immersed, just perforating the epidermis with the minute pierced ostiole; texture very thin and soft, sinuately prosenchymatous, pellucid, ochraceous-brown, thicker and darker just around the ostiole, where the cells are distinct and parenchymatous. Spores oblong-fusoid or oblong-cylindrical, straight or angularly bent, or slightly curved or flexuous, obtuse at the ends or slightly pointed below, plainly 3-septate when mature, often with one or two guttules in each cell, sometimes faintly constricted at the septa, or more strongly at the middle one, about 15-16 mic. long when 1-septate, 20-26 by 2½-3½ mic. when mature, singly colourless, but very abundant and long remaining clustered together in masses which generally showed a faint pinkish-isabeline tinge.

"As for the pycnidia on the glumes, the only difference was that they were larger, more erumpent, and prominent; the spores were identical. On the nodes the spores were the same, except that in the Cheshire specimens they were slightly narrower (2-2½ mic.) and in those from West Australia many were quite 3½ mic. wide. They were either non-septate or had one, two, or three septa, with frequently one or two minute highly refringent oil-guttules at each end, and on each side of the septa. The nodes show the pycnidia best after the leaves have withered; then the node shrinks and falls in, being fully invaded by the mycelium, which of course, stops the flow of sap and kills the host. The part of the node occupied by the pcynidia assumes a more reddish tinge, and the pycnidia become more prominent. There cannot be the slightest doubt that all three forms belong to the same species, occurring on the leaves, the nodes, and the glumes as the host plant advances in age."

Grove's description fits Arkansas material very well.

Kuehn (14) described *Phoma Hennebergii* as the cause of the

spotting of glumes and beards of summer wheat in Germany. His description of the fungus is as follows:* "Perithecia (pycnidia) sparse, covered at first, finally with a round aperture, vertex mostly concave, about 0.1 mm. in diameter, dark, interior whitish; stylospores cylindrical, straight or slightly curved, 14.3-17.2 mic. long, 2.3 mic. wide, hyaline." In comparing this with other fungi found on the same host he states that it differs from *Phoma* (*Darluca*) *Filum* Cast. in the form of the spores, from *Phoma graminicola* Fuck. in the size of the spores and from *Septoria Tritici* in both shape and size, the *Septoria* having much longer and much narrower spores than *Phoma Hennebergii*. Concerning the spores he makes these additional remarks. Upon maturity they take the form of cirri (slightly curved or straight, thread-like bodies) and germinate immediately. They swell upon germinating presenting a wavy appearance because of the formation of one or more faint wrinkles; partitions do not appear. The germ tubes develop most frequently at the ends of the spores, although they may also appear at the sides. Near the spores there are found occasionally peculiar bladder-like extensions.

Kuehn's description, as a whole, is applicable to the Arkansas material. The following exceptions and additions are noted. The pycnidia are quite often numerous, particularly on the outer glumes, but owing to their size and origin they are readily overlooked, even with a hand lens. They are of subepidermal origin and vary considerably in size, the average being from 75 to 100 mic. When seen from above they appear globoid, cinnamon-brown in color with a round or oval ostiole at the apex, which measures 4-12 mic. in diameter; surrounding the ostiole the hyphae assume a much darker shade than the hyphae of the remainder of the fruiting-body. The spores even at maturity vary considerably in size, shape and in partitions. The average spores in Kuehn's material measure 15-18 by 2.8-3.0 mic., with occasional spores which are somewhat longer. Arkansas material at maturity, judged by the power to germinate, usually shows spores that are longer than the average spores of the European material, although pycnidia are readily found whose spores are no larger than the European spores. The average measure 18-25 by 2.8-3.0 mic.; spores measuring up to 30 mic. are not uncommon. In shape, the European as well as the American material agree, the average being cylindric with rounded apices and usually truncate or narrowed bases, and often slightly curved, although straight spores are common.

Kuehn's idea that no partitions are present is at variance with Eriksson's findings and with those of the writer. Kuehn's

* Peritheciis sparcis, primotectis, deinde apertis rotundatis, vertice plerumque concavis, circ. O. 1 M. M. diam. atris, nucleis albis; stylosporis cylindraceis, rectis vel leviter curvatis, 14.3-17.2 Mik. long. 2.3 Mik. crass. hyalinis.

own material shows spores in which one cross wall in the equatorial region is common. Indeed, spores with two or three cross walls are not difficult to find, and that these are true partitions and not merely wall markings is made obvious by the shape which the spores assume upon germination. The spores as a whole swell or extend outward when germinating, except at the places where cross walls are noted, and at these loci the spores do not swell but appear constricted, thus giving them a wavy appearance. Kuehn noted this feature and there appears to be little doubt that the "Einschnuerungen" refer to constrictions brought about by the presence of cross-walls. Mature, viable spores often show slight indentations at the cross-wall even while they are not germinating. Apparently, the presence or absence of cross walls is not always associated with degree of maturity, if maturity is gauged by the ability to germinate. (One-celled spores have been observed to germinate as readily as two- or more-celled spores.)

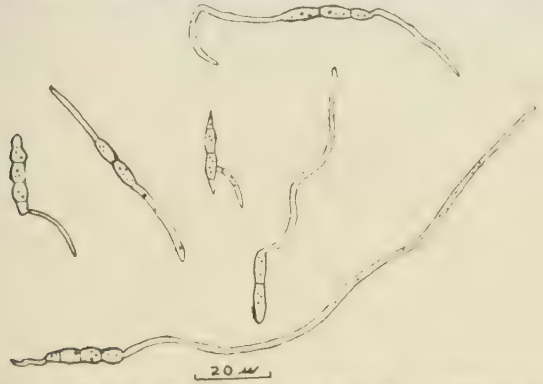

Fig. 3. Germinating spores of *Septoria nodorum*. (Material overwintered in the laboratory.)

The writer's observations upon the germination process agree well with Kuehn's. (See fig. 3.) The spores usually germinate from one or both ends, and sometimes from the sides. Material collected in the early summer and kept in the laboratory until the following May, germinated very readily, as much as 95 percent in some material. Pycnidia macerated in a drop of water and kept in a moist chamber overnight show numerous germinating spores the following morning. The germ tubes are hyaline, delicate, 2-4 mic. thick, and rapidly growing, sizes up to 150 mic. in length in 24 hours germination being not uncommon. At first, branching and septation are rare, but within 48 hours numerous, short, side-branches and frequent cross-walls appear.

Genetic Relationship of the Parasite

It has already been noted that Kuehn described the fungus which he found in the glume-spots as a species of *Phoma*, namely *P. Hennebergii* nov. spec. No one, as far as the writer knows, has as yet questioned the validity of this species, all mycologists who have noted it, including Saccardo, accept this as a good species. The genus, however, in which this was first placed has been questioned and there is reason for still questioning any decision that may be made in this direction. In erecting the genus *Macrophoma*, Berlese and Voglino included *Phoma Hennebergii* as one of the species, since the ostiole is not markedly papillate, the pore is small, and since the spores measure more than 15 mic. Mention has already been made of the fact that Eriksson describes and figures the spores as being uniseptate, and that the writer finds the spores extremely variable with regards to partitions, uniseptate spores being very frequently found along with spores showing no septations or as many as three.

The matter of septation in the Fungi Imperfecti is extremely important from a taxonomic view point, and as far as most fungi in this group are concerned this is probably a good diagnostic character. As far as the fungus here described is concerned, the genus *Phoma*, *Macrophoma*, *Phyllosticta*, *Ascochyta*, *Stagonospora* as well as *Septoria* might be used with equal validity. It perhaps would be preferable to consider this fungus in the genus *Ascochyta*, since many, if not most, of the spores are uniseptate, and since the scolicosporous nature of the spores is not very evident, when compared with ordinary Septorias, such as *S. graminum*, *S. Tritici*, *S. Lycopersici*, *S. petroselini*, etc. Indeed, it did not occur to the writer that the fungus under discussion might be considered a *Septoria* until Dr. J. J. Davis identified the material sent to him, as *S. Avenarum* Pass. Attention might also be called to the fact that numerous European mycologists and pathologists including Saccardo, Sorauer, Frank, Diedicke and others described *Phoma* (*Macrophoma*) *Hennebergii* and *Septoria nodorum* (*S. glumarum*) as two different fungi. Even Grove who has gone over the species of *Phoma* listed by Saccardo and who pointed out the similarity between *Septoria glumarum* and *S. nodorum* does not show this relationship.

The possibility that other species of *Septoria* described on the Gramineae may be the same as *S. nodorum* should not be overlooked. Diedicke (7) lists twenty species of *Septoria* on the Gramineae, most of which have the long, narrow spores of the *S. graminum* and *S. Tritici* type. There is one form, however, described as *S. fusispora* Died. new species (p. 467) on *Triticum* (*Agropyron*) *repens* whose spores measure the same as *S. nodorum*. The necessity of culturing these fungi and attempting artificial infections

before assigning relationships is as evident in this group as in other groups of fungi.

That the fungus under discussion is different from *S. graminum* and *S. Tritici* there can be little doubt. The latter fungi, which have been considered as the same species by some mycologists, are known to be present in this country and often do considerable damage in cool weather during the spring of the year, around Fayetteville. The writer has studied this Septoria, (for convenience it may here be considered as one species, *S. [illegible]*), and has carefully compared it with the one which attacks the glumes as well as the leaves, and invariably finds *S. graminum* possessing very long, narrow spores, (40-60 by 2.5 mic. is the measurement of the average spores), while the glume spotting fungus always has much shorter spores, 18-25 mic. being an average. The recent observations by Johnson (13), Beach (2), and Cromwell (5) on Septoria of barley and of wheat, speak only of leaf and seedling infections, no reference is made to any glume spotting. Johnson refers the fungus on barley to *S. graminum*, Beach refers to *S. Tritici* and Cromwell does not give any name. It appears that while *S. graminum*, or related forms, confines itself to leaf attack, *S. [illegible]* may attack almost any part of the plant above ground. Artificial infection experiments seem to confirm this view. It is interesting to note the difference in temperature relationship. *S. graminum* attacks mostly during cool weather, while *S. nodorum* is primarily a warm weather pathogen, attacking the plants when they have made considerable growth, doing most of its damage after the plants have produced heads.

There are fungi going under other names than those already discussed which may be the same as *S. nodorum*. Durrell (8) describes an *Ascochyta*, probably *A. graminicola* Sacc., on dead wheat straw. He describes pycnidia as filled with guttulate spores which are usually two-celled and approximately 12-20 by 3.5-4 mic. His measurements would indicate a fungus whose spores are wider than spores of *S. [illegible]*, but the possibility that the same fungus is involved should not be overlooked.

Davis (6) describes *Ascochyta graminicola* on *Calamagrostis canadensis* and the writer finds, on comparing the glume-spotting fungus with material kindly furnished by Dr. Davis, that the Ascochyta spores of his material are usually shorter and differ markedly in shape; they are fusiform and noticeably acute at both ends, while the other spores are cylindric, usually rounded above and truncate or narrowed below, never acute.

The fungi mentioned above are the only ones thus far found which deserve consideration. In this preliminary publication the writer is not attempting to give a complete and final list of synonyms or of morphological features. This, together with other

problems not yet solved remain for the future. A provisional technical description of the fungus follows:

Septoria nodorum Berk.

Synonyms:

Septoria glumarum Pass.
? *Septoria fusispora* Died.
Phoma Hennebergii Kuehn
Macrophoma Hennebergii (Kuehn) Berl. and Vogl.
? *Ascochyta graminicola* Sacc. in part.

Spots indefinite, often eliptical or elongated-eliptical, varying in color from a greyish-brown to dark-brown or purple-brown, often appearing light-grey on a purple background. Compared to Ridgway's color charts, Dresden brown, Saccardo's umber, bister, and other colors may be included; occasionally a yellow indefinite halo appears around the brownish discoloration, but this is not as distinct as the halo usually found around brownish discolorations due to *Septoria cruciata*. Pycnidia gregarious on spots of glumes, stems and leaves, inconspicuous, subepidermal, opening by a small oval or roundish pore, golden-brown at first, finally blackish, globoid, measuring 60-100 mic. in diameter. Spores cylindric, curved or straight, colorless, often adhering and issuing from the pycnidia in the form of serpentine threads, one to three septate, 18-25 mic. long by 2.8-3.0 mic. wide, rounded above and truncate or narrowed below, with or without guttulae.

Artificial Infections

Since no infection experiments have apparently been reported for this pathogen up to this time it may be worth while to present briefly the results of artificial infections. Wheat plants growing on a greenhouse bench were moistened by a water-spray and material containing spores was smeared on the moistened leaves and glumes. The spores in some experiments were obtained from pycnidia on material collected the previous summer and kept in the laboratory over winter, and in others were obtained from material of the current year. Inoculated plants were kept under large belljars, usually for three days, to prevent drying out, and where plants were too large to go under jars the inoculated parts were covered with large test tubes which were plugged with moistened cotton. Various leaf and glume infections were obtained (see fig. 4) with the production of pycnidia on the spots. The pycnidia bore spores which agreed in every respect with those observed in natural infections and it is interesting to note that spores coming from pycnidia born on glumes produced leaf infections and spores coming from leaves were able to infect glumes.

Fig. 4. Artificial leaf infections, brownish discolorations with yellowish halos. (Slightly enlarged.) Green parts of the leaf are not shown.

The symptoms induced by artificial infections were very similar to those of natural infections.

Extent of Injury

Attention has already been called to the serious nature of the disease as reported from Germany and Sweden and to Townsend's report of severe damage in Maryland. The studies thus far concluded by the writer do not warrant any definite statement concerning the amount of damage. It is certain, however, that the disease is serious and according to observations made thus far it would stand next to leaf rust, (*Puccinia triticina*) which is the most serious disease of wheat in Arkansas, in amount of damage done. Leaf, stem, and head invasion all tend to weaken the plant, to produce undersized, shriveled kernels and to reduce the yield materially. Prof. L. W. Osborn in conversation with the writer, reports that the weight per bushel of wheat produced on the University farms during the last year has been lowered several pounds and he has associated this loss with marked discoloration of the heads.

A large number of wheat varieties have been attacked, among which are the standard winter wheat varieties, particularly the common red, winter wheats, including Red May, and Kan Red.

How widespread this disease is remains to be ascertained. It has been located in Independence County as well as in Washington County, two widely separated regions in this state and a careful survey would probably reveal its presence in other localities.

Experiments involving the possibility of controlling or eradicating this disease will be undertaken in the future. It appears that the use of early maturing varieties and proper crop rotation, practices which are ordinarily recommended for this region, should help in controlling this disease. The use of clean seed, preferably seed coming from farms which are known to be free from this disease, cannot be too strongly recommended.

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